ENERGY PRODUCTION

CHINA'S ENERGY DEVELOPMENT IS HAMPERED NOT BY A LACK OF RESOURCES, BUT BY A LACK OF SUPPORT INFRASTRUCTURE

E N E R G Y   R E S O U R C E S

A. OVERVIEW

Despite a wealth of raw material, China's physical size and incredible population of 1.2 billion strain available resources. It is easy to consider China an energy poor nation on a per-capita basis, despite the abundance of energy resources.

However, China's most significant energy resources problem is not extraction or development, but distribution. Almost without exception, energy resources are in the wrong places: far from consumption centers and hard to reach. Energy resources are found everywhere but in south-central China, where the people are, making transportation and distribution infrastructure a critical part of Chinese energy planning.

For instance, existing rail capacity is insufficient to handle the large volumes of coal being produced at the northern mines. Annually, upwards of 20 million tons of high grade coal is forced into temporary storage at mines in northern China for lack or rail transport. Reportedly, one mining area has more than 60 million tons stockpiled, while power plants in southern China are forced to burn low grade coal from the closer mines.

Other resources fair just as poorly. China's developed oil fields are in the northeast, while new oil prospects are in the far western desert. Due to its expense natural gas has been largely passed over by the Chinese and left to foreign developers, but gas resources are typically linked to petroleum and have the same unfortunate geographic distribution. Populated central China is also far from geothermal sources, as well as perpetually cloud covered and calm most of the year making thermal, solar and wind generation unworkable alternatives. In fact, the only geographically available resource is hydropower, and most of these sites are small, low capacity rivers unsuitable for powering industry.

This means that to supply electricity, energy resources must be transported from the north and west. Coal is brought to thermal plants by rail, tying up 42% of the freight capacity. Oil is sent through long and expensive pipelines. Hydropower has to come from the construction of large dams which raise environmental concerns and occasionally require the relocation of entire districts (the controversial Three Gorges Project is an example of this). Along with the demand for commercial energy, huge volumes of biomass are consumed as fuel for cooking and heating. Again, the even modest per-capita consumption by this incredibly large population makes preservation of forested areas a real concern.

Two scenarios have been generated to estimate energy supply to the year 2015. One is a "Standard Supply Scenario" which is an anticipated minimum production case, and the other is a "Maximum Supply Scenario" which offers a more optimistic production ceiling. Actual production will lie somewhere between the two, probably slightly above the Standard scenario levels[1].

Annual growth in China's energy resources has varied dramatically over the past twenty years, ranging from a peak annual growth of 21% to an annual low of -12% (a loss) in the case of natural gas. However, despite such swings, overall growth been relatively smooth. The Standard Supply Scenario was modeled by assuming the average growth rate of the past decade would continue, while the Maximum Supply Scenario assumed that the occasional extraordinary production growth rates could be repeated and sustained.

GROWTH RATES BY ENERGY RESOURCE				
GROWTH RATES	**COAL**	**OIL**	**NATURAL GAS**	**HYDROPOWER**
20 year high	14.32	17.32	20.58	14.29
20 Year low	-2.39	-4.67	-12.04	-9.66
Standard Scenario Rate	4.65	2.93	2.93	5.53
Maximum Scenario Rate	7.50	5.00	5.00	11.00

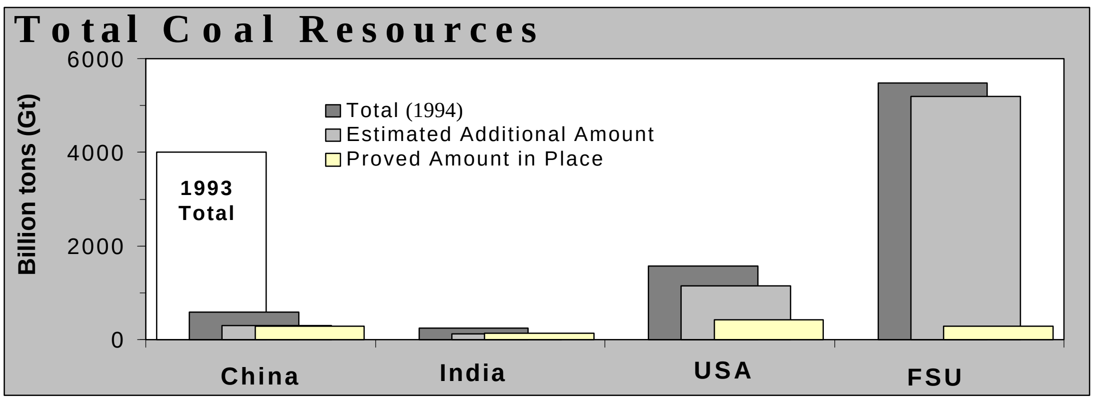
B. COAL

[1] Standard scenario represents spending levels at 6% of GDP, near current costs. See "Costs, Finance & Trade" in this section under 'Total Costs to Supply Energy Resources & Electricity"; see also Summary, Section I to see how this scenario matches demand curves.

Implementation of Chairman Mao's "industrial progress" plan required increases in steel production, rail transportation and electrical power. All of these required coal. It is fair to say that coal literally powered Chinese industrialization, and today continues to dominate Chinese energy policy.

In 1993 the Chinese consumed 1,139 million tons (Mtons) of raw coal accounting for 73.1% of the nation's total primary energy consumption [CED'95 IV-1.3]. In the past decade consumption has grown faster than total energy consumption, with growth rates of 5.9% and 5.2% respectively, indicating that coal continues to be the most accessible and popular energy source [CED'95 IV-1.4].

1. Coal Production



Coal bearing sediments cover over 5% of Chinese territory (550,000 km^2) with deposits in every province. Total coal resources have been estimated by the Chinese at 3.2 trillion tons but Chinese numbers must be weighed carefully. The Ministry of Energy once estimated total coal resources at 9.6 trillion tons, more than the global total [Smil p.31]. Even in 1987 (published 1993), through the use of unique and unrealistic classification schemes, Chinese estimates placed total coal resources[†] at 4.0 trillion tons with recoverable reserves[‡] totaling more than 167 billion tons [CED I-7]. Current World Energy Conference (1990) figures, using western classifications of Proved Amount in

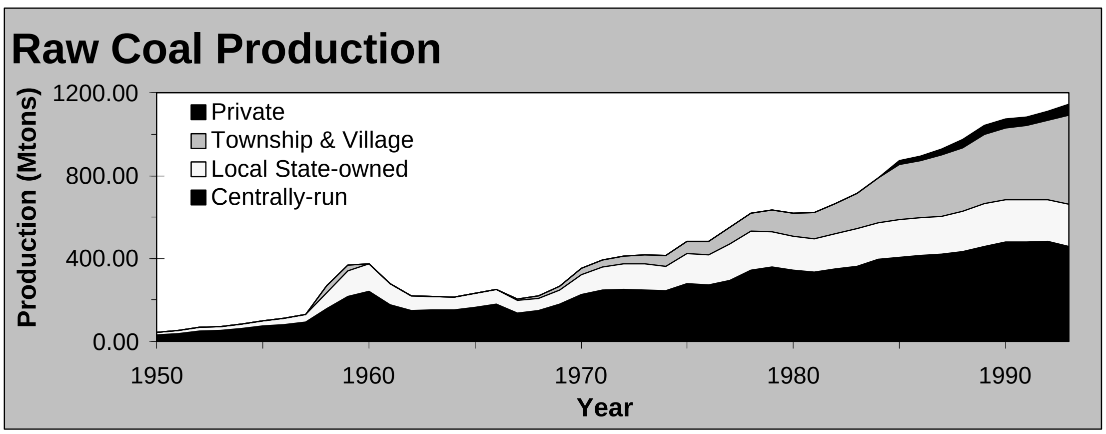
---

[†] Unless otherwise noted, in this report "total resources" refers to the sum of World Energy Conference *Proved Amount in Place (PAP)* and *Estimated Additional Amount in Place (EAP)* numbers. *Proved Amount in Place (PAP)* is defined as "the [amount] that has been carefully measured and has been assessed as exploitable under present and expected local economic conditions with existing available technology". *Estimated Additional Amount in Place (EAP)* is defined as " the indicated and inferred [amount] additional to the PAP. It includes estimates of amounts which could exist in unexplored extensions of known deposits or in undiscovered deposits in known fuel-bearing areas as well as amounts inferred through knowledge of favorable geographic conditions. Deposits whose existence is merely speculative are not included".

[‡]"Recoverable Reserves" in this report refers to the British Petroleum Category of Proved Reserves, defined as "those quantities which geological and engineering information indicate with reasonable certainty can be recovered from known reservoirs under existing economic and operating conditions". In most cases, this is slightly lower than the *Proved Amount in Place* as described above.

Place (PAP) and Estimated Additional Amount in Place (EAP) drop that total by 85% to 591 billion tons total, with recoverable reserves down 32% to 114.5 billion tons.

Despite such drastic changes in resource estimates, China still leads the world in actual coal production at 1116 Mtons, with the closest followers being the US at 823 Mtons, and the former USSR at 412 Mtons (1994 data). China has 2242 coal mines, with an average annual mine capacity of 100,000 tons. Just under half of production is generated by state-owned mines, with the largest controlled by the China National Coal Corporation (formerly the Ministry of Coal and Industry). State mines average an annual 9.6 Mtons output, with the largest producing more than 30 Mtons. Coal produced at Ministry mines is rationed, distributed at a subsidized price to State enterprises, then what remains is traded at market prices. In areas where coal is available in quantities too small to merit the attention of the central government, state-owned but locally supervised small and medium sized mines are operated to meet local demand. These smaller local government mines contribute about 20% to China's coal production.

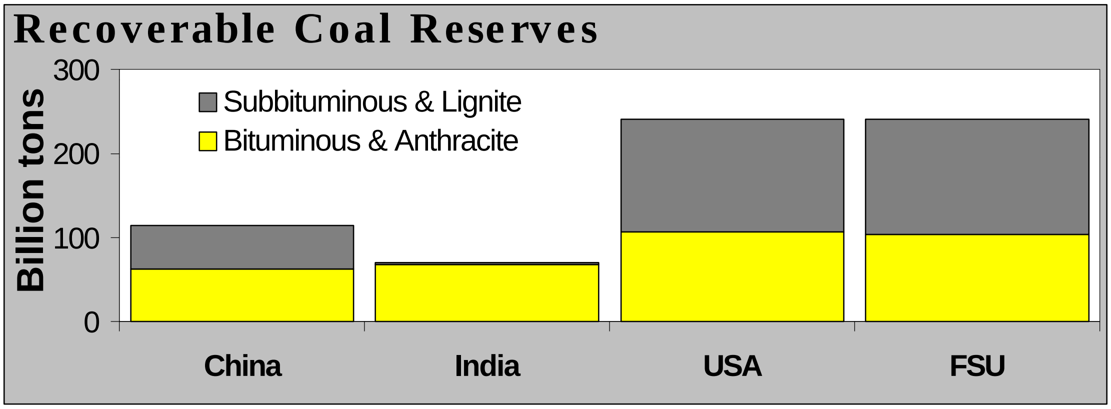


The remainder of coal production is conducted by privately owned, small scale mining companies. In the late 1970s the Chinese government passed several economic reforms allowing private ownership of mines as a means of increasing production with minimal state investment. Since then these rural-collective mines (both private and village owned) have accounted for almost all growth in coal production [OSD p.II-17].

2. Types of Coal

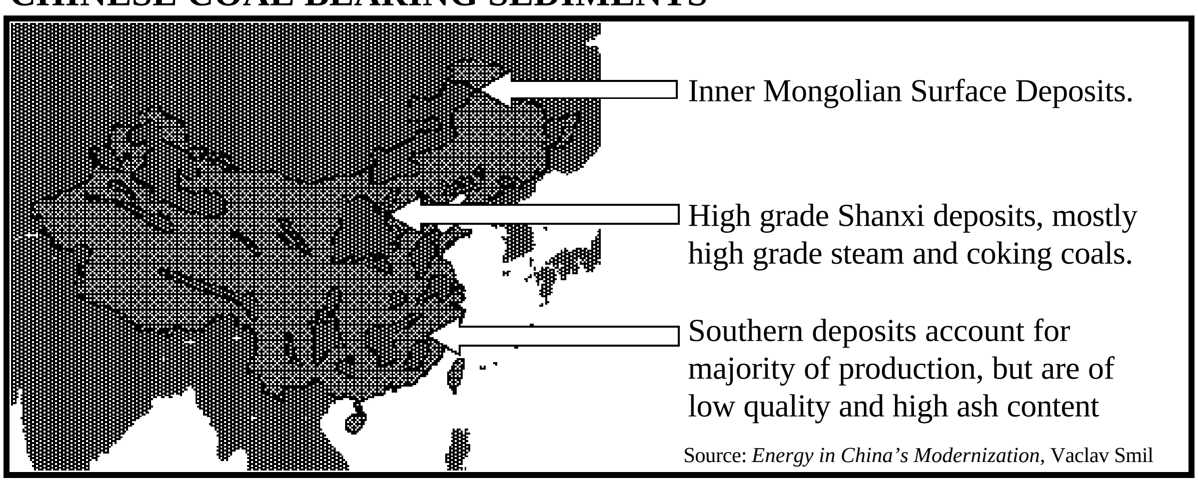
The most prominent reserves of hard coal are bituminous (high grade steam and coking coals) with less than 1% sulfur content. The Ministry of Energy estimates its coal reserves at 79% bituminous (59% steam coal and 20% coking coal), 6% anthracite and 15% lignite [CED p.I-7(d)]. Compared to other countries Chinese coals have a high percentage of anthracite with high ash/heat and low sulfur/heat ratios.

In general, the high quality reserves are found in northern China, where eighty percent of the total reserves are found. The Shenfu field in northern Shanxi produces high grade coal with low ash content (6 to 7 percent before washing) and low sulfur content (0.5 to 0.6 percent) making it very attractive on both domestic and international markets [Dorian & Fridley, pp. 60-61]. Unfortunately, the majority of mined coal comes from the south, and has both a low equivalency rating (tce/ton) and often a very high sulfur content, up to 20% from some mines.



Steel production has historically been seen as the cornerstone for industrial development, and in the past Chinese Ministry officials have demanded large volumes of coking coal to fuel steel production. However, politically motivated estimates for steel industry growth were greatly inflated and in 1988 only 89 of the 463 million tons of coking coal produced were used for coking [OSD, p.II-19]. With export capacity limited, most of this high grade and expensive coal was consumed domestically as steam coal or household fuel. Such non-industrial consumption of export quality fuel was a waste and since then the percentage of coking coal extracted from bituminous coal seams has dropped from 63% to 20% in an effort to preserve the resource. Globally, high grade coking coals are relatively rare, so their use in China as a boiler fuel is not desirable.

CHINESE COAL BEARING SEDIMENTS



Source: *Energy in China's Modernization*, Vaclav Smil

3. Mining and Processing

Compared to those found in the US or former Soviet Union (FSU), Chinese mining conditions are unfavorable. Coal seams are thinner, deeper and further from consumption centers making both extraction and transportation expensive.

Ministry owned mines collect approximately 11% of their output from seams thinner than 1.3 m, 43% from 1.3-3.5 m seams and 46% from seams thicker than 3.5 m. By comparison the average US seam is noticeably thicker at almost 5 m [OSD p.II-19]. However, Chinese seams are relatively flat and accessible, with only 5% having difficult or steep inclines. The high organic content of Chinese coal, responsible for the high ash and sulfur contents, leads to mine gas accumulation. Almost half (45%) of the operating mines have a high potential for methane accumulations and explosions [Smil, p.32]. Coal production is further hampered by a lack of surface deposits. Production from relatively inexpensive surface mines is only 4%, compared to 60% in the US and 40% in the former USSR [OSD p.II-20]. Most of China's proven reserves lie between 300 and 500 m depth and require multiple deep shafts to work a seam, making operations capital intensive.

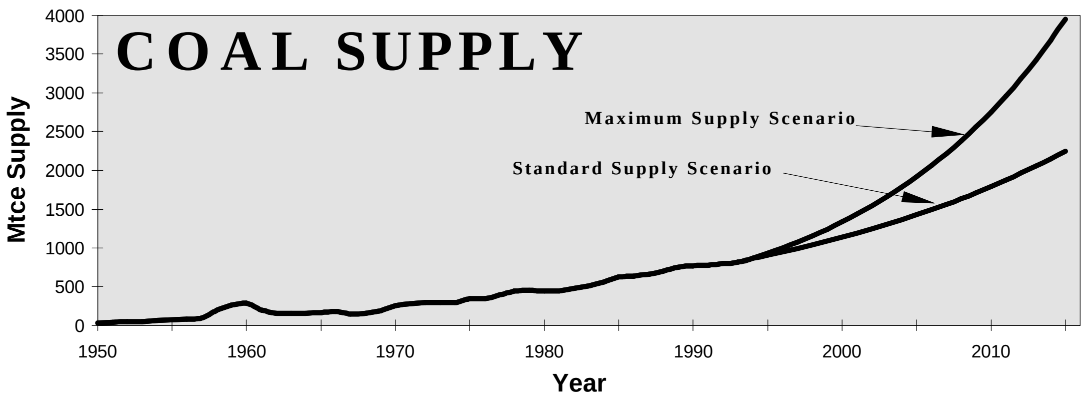
Because the mines themselves are so very expensive, China has been slow to mechanize. Even in the state supported Ministry mines, in 1988 only 31.4% had fully mechanized processes, and of the remainder only 58% had mechanized extraction. The smaller, lower budget, locally supervised mines have a much lower mechanization rate. In many rural areas extraction is done manually. This makes Chinese labor productivity quite low. Ministry owned mines (with 58% mechanized extraction) average 1.1 tons per miner-shift, while the US average is 23 tons [OSD p.II-20]. If the rural mines were included in this average, the Chinese statistics would be considerably lower.

In the past decade international pressure and domestic awareness have forced the Chinese to pay closer attention to the environmental consequences of heavy coal use. Of great concern is the release of sulfur from thermally inefficient and environmentally damaging unwashed coal. In response, the Chinese have begun shifting mining operations to the northern provinces where higher grade coal can be mined and some development of coal washing facilities is underway. However, treatment is expensive and the government has balked at the investment required to treat the volume of coal consumed annually. Currently only 17% of Chinese coal is washed, and more than 80% is consumed with no treatment at all [CED II-10]. Cost analysis of the increased energy per ton, improved end use combustion, reduced pollution and decreased transportation costs has encouraged China to wash coal for those industries which require high grade fuel for industrial processing, but other industries and consumers must do without. Present washing capacity is 190 Mtons per year (1988) with 170 Mtons actually washed; 70% of this capacity is devoted to coking coal for the steel industry.

4. Planned Development

China anticipates a national production capacity, not including rural collective mines, of at least 1400 Mtons per annum by the year 2000. 40 Mtons of current production capacity will be non-productive by this time, requiring not only an increase in efficiency at existing mines but expansion into new beds.

Much of the planned development involves surface mining in the northern provinces of Shanxi and Inner Mongolia. China hopes to use its limited surface reserves to meet the immediate demand in electrical power generation for steam coal. The six large surface mines operating in Shanxi-Mongol region expect an annual production of 280 Mtons by the year 2000. To meet such goals production will be stepped up dramatically. For instance, the Shengfu-Dongsheng surface mine's current output of 30 Mtons per year of steam coal is expected to double to 60 Mtons in the next five years [OSD p.II-21].

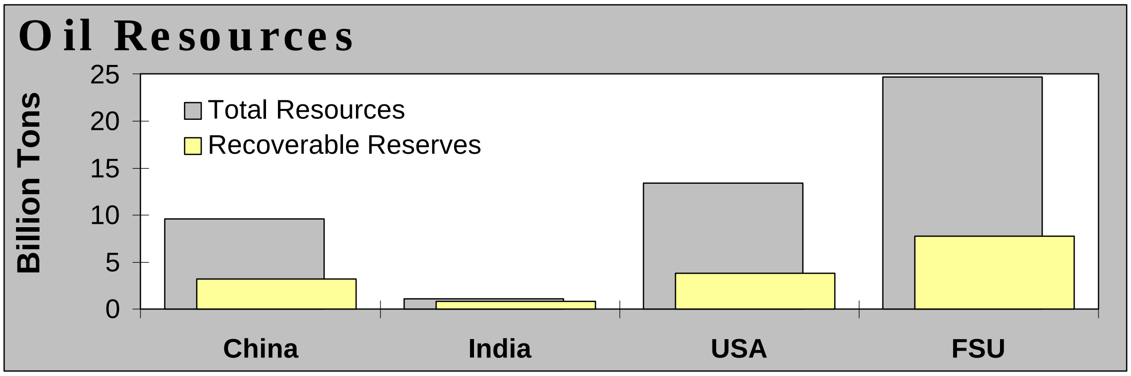


In the past decade, coal production has grown at an average of 4.65% annually. The Standard Supply scenario projects this rate out to 2015, assuming that growth in Chinese coal production will not fall below this. Note that the State capacity prediction of 1400 Mtons (999 Mtce) only corresponds to a growth rate of 2.5%. The difference between this rate and the Standard rate is accounted for by the production of small private and rural-collective mines not included in the State estimate. A ceiling rate was calculated for the Maximum Supply Scenario from the best five years for production capacity increases, resulting in a maximum annual average growth rate of 7.5%.

C. PETROLEUM PRODUCTS

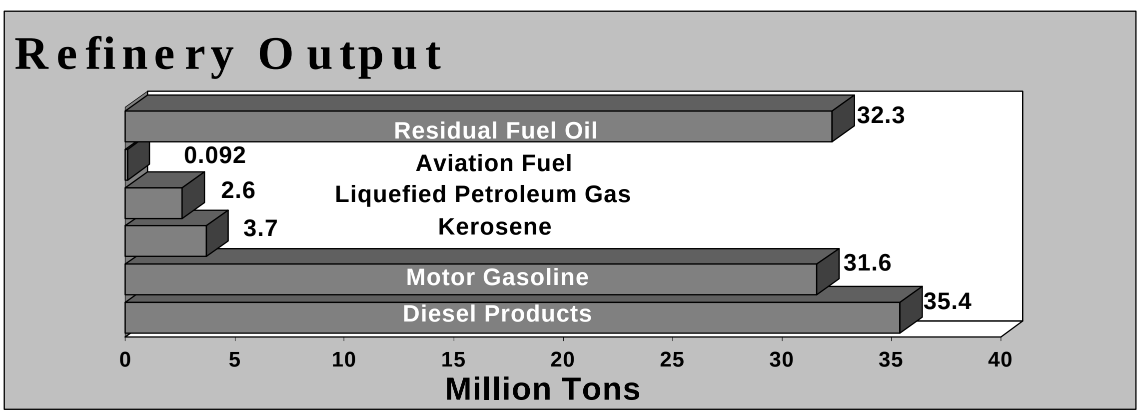
In 1957, sixty percent of China's oil was imported. Development of oil resources in the 1960s and 70s allowed China to experience an oil "boom" with 25% annual growth and to achieve a measure of energy autonomy. With petroleum production growing so rapidly, China began exporting oil, peaking at 6.21 Mtons in 1985. Unfortunately as domestic consumption continued to increase while production stagnated, the level of exports dropped and in 1993 China again became a net oil importer [CED t.VII-1].

The quality of the initial petroleum reservoir surveys in the 1950's and 60's, accompanied by hype and blatant exaggeration by the State led to disappointments in both industry growth and annual production yield. One early statement by the Ministry of Energy claimed reserves in excess of 50 billion tons, putting China ahead of Saudi Arabia. Since the 70's, much of the exploration (especially offshore) has been conducted by foreign companies resulting in far more modest reserve estimates. Current estimates are 9.6 billion tons for total resources † with recoverable reserves estimated at 3.3 billion tons ‡ [CED p.I-8].



1. Oil Production

Despite grandiose claims, China has been unable to produce crude on a scale approaching the old State predictions. Production in existing fields is disappointing, and many alternative fields in the western deserts and offshore in the South China Sea are being developed in an effort to boost production.



The first Chinese oil was discovered in north-eastern China's Songliao basin near Daqing in 1959. These now heavily developed fields were the backbone of China's oil industry, generating a 23.9% annual production growth rate even with obsolete technology from 1968 to 1976. However, maturation of the field, severe under-investment and a lack of technical expertise caused a drop in production in 1977. With aid from foreign companies and an infusion of western technology, production rates climbed slightly in the early 1980s, but almost immediately again stagnated. Since 1985 Daqing has seen 0.0% growth

† World Energy Conference sum of PAP and EAP numbers.
‡ BP category Proven Reserves.

in output, even with the addition of multiple new drilling sites. As a whole, the Chinese oil industry has seen only 1.4% growth since 1990.

In 1994 China produced 147 Mtons of crude, with almost 5 Mtons from off-shore wells. China has 33 medium and large oil refineries (1988) with a 145 Mton distillation capacity. 1993 throughput totaled 131 Mtons with a production total of 117 Mtons [‘93UN, t16]. Refineries produced 35.4 Mtons of diesel products, 31.6 Mtons of motor gasoline, 3.7 Mtons of kerosene, 2.6 Mtons of liquefied petroleum gas and 92 thousand tons of aviation grade fuel with 32.3 Mtons of residual fuel oil [‘93 UN, t26].

2. Crude Oil Characteristics

Chinese crude is heavy and found in small complex geological structures. Consequently reservoirs are small and thin, containing high density crude that reduces cavity pressure and requires artificial displacement for extraction. Ninety percent of the Chinese wells require early secondary extraction and use water injection to pump crude. These physical constraints, combined with generally outdated technology push China’s recovery rate down to about 27%. However, cheap equipment and inexpensive labor allow oil to be extracted at competitively low prices despite these difficulties.

3. Planned Development

Offshore exploration led to the installation of a few platforms in the South China Sea but production has been disappointing. More promising is the development of the Tarim basin in western China’s Xinjiang Province.

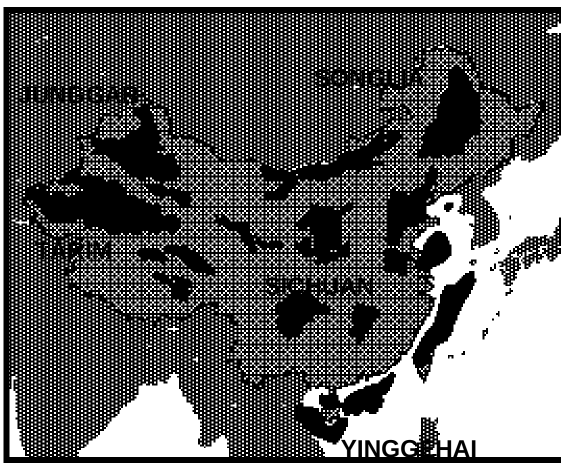
Enthusiastic oil companies once estimated the reserves of oil and gas in Tarim (about the size of France) at up to 10 billion tons. Most of those estimates, especially the older ones from the late ‘70s, were based on extrapolation from existing foreign basins of similar stratigraphy, but this assumption that China’s resources will bear out like those in other countries is not yet supported by any evidence. Unless, of course, one believes the tee-shirts worn by Tarim drillers which read “The Great Hope of China’s Oil Industry.” Unfortunately several years of publication in the popular press and the Ministry of Energy’s *Yearbook of Chinese Energy* have allowed the Tarim myth to be perceived as reality.

Even if the basin does not have reserves as large as the State would like, development in Tarim is currently China’s only hope of minimizing oil imports. Production rates are climbing but there is still some doubt about the regions total production capacity. The recent surge in production can be directly linked to the expansion of the single railway line into the region, allowing the construction of new drilling stations. Output surged from the 1990 total of 150,000 tons to 1.95 million tons in 1994. 1996 production is expected to approach 5 million tons, more than double the 1994 total, but again, this growth is large only because prior to 1994, there was almost no development of the region. Further, though much publicized, the estimated 1996 total of 5 million tons is only 3% of the expected ’96 national production total, and cannot compare to the output of the Daqing or Shengli fields which produced 56 and 31 million tons respectively in 1994. Even China’s fledgling offshore industry is expected to produce almost double the Tarim figure in 1996, with a total of 8 to 10 million tons [Reuters 300812Z,].

The only credible estimates for total production capacities are based on current production rates, plans for expansion and confirmed reservoir discoveries. The 1986 global study by the *Oil and Gas Journal* puts China’s recoverable reserves at 2.6 billion tons [‡] [Smil. p.37]. This has since been upgraded by DOE to 3.2 billion tons [‡2], but is still considerably lower than Chinese Ministry figures.

This rejection of Ministry figures is not an indication that China’s petroleum industry has no future. The three major fields being worked in the Tarim basin have potential and are the country’s most important oil development area. There are problems in that western China has very little transportation or communication infrastructure, making both construction of refineries and transportation of oil out of the region difficult. Projects currently underway to ease these difficulties include pipeline construction and railway expansion. Currently 60-70% of Xinjiang’s rail traffic is devoted to oil transportation. The recently completed expansion of the Lanzhou-Urumqi line to dual track will partially relieve the bottleneck, but a 1,000 km pipeline from Xinjiang to the refineries in Sichuan (central China) is under construction at a cost of ¥ 5 billion to further alleviate strain on the rail system.

CHINESE HYDROCARBON BASINS



Ailing production in north-eastern China is expected to be replaced by new oil sources in the western desert, specifically a basin about the size of France called Tarim

Source: *Energy in China’s Modernization*, Vaclav Smil

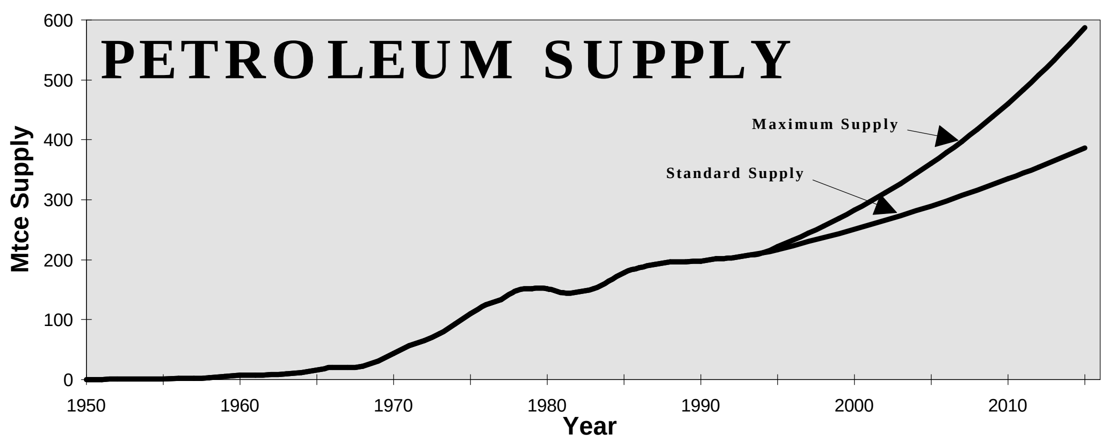
The greatest threat to Chinese oil production is the very real possibility that the Daqing reserves in Songliao may soon be exhausted. The decrease in production during the late 70s and early 80s only leveled off (and has remained at 0% growth since 1985) because oil companies began drilling layers as thin as 0.2-0.5 meters. More than 50% of Daqing’s recoverable reserves have already been extracted, and those remaining have a high water

‡ BP category Proven Reserves.
‡ BP category Proven Reserves.
2 As quoted in LBNL’s *China Energy Databook*, p. I-7

content (>70%) due to pressurized injection as a secondary recovery technique. Interviews with Daqing area residents reveal that to sustain production, pumps have been installed in playgrounds, parks and even small strips between houses.

In addition to the obvious expenses of constructing new drilling stations and refineries if Daqing fails there are many additional associated costs. The existing Daqing fields are near China's industrial centers, so oil transport has never been a major issue. However, the shift of industrial growth to south-east China and the Yangtze river basin will require either new pipelines or alternate oil transport methods. This need may be partially met by the new pipeline from western Xinjiang to central Sichuan, but further development of either this pipeline or the closer offshore platforms will be necessary.

The US State Department estimates that China could face up to an 80 million ton shortfall by 2000, and quotes unpublicized Chinese Ministry estimates of a 50 million ton shortfall. Our projection estimates the Chinese shortfall at between 42 and 64 million tons in the year 2000, equivalent to 817 thousand to 1.3 million barrels per day (see Summary). These figures are a closer match to the Chinese estimates than the slightly higher State department figures. In either case, the shortfall will spur new development of domestic Chinese oil resources.



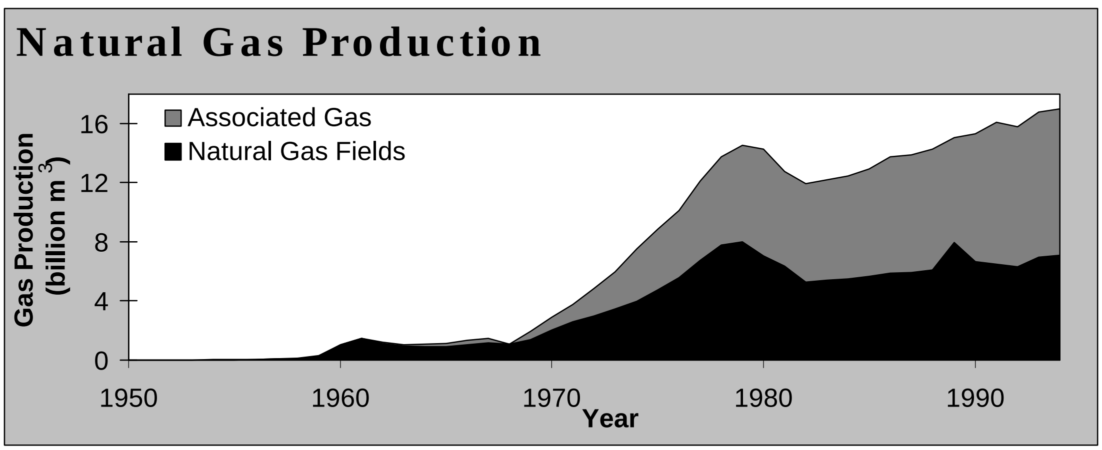
For the Standard Supply Scenario, a growth rate of 2.93% was used, with a ceiling rate of 5% used for the Maximum scenario.

D. NATURAL GAS

China produces very little natural gas and output growth has recently declined. Petroleum has always, and will continue to be the Chinese priority. In other countries, this minimal growth would be indicative of small reserves, which is not the case in China. However, the growth may increase with new discoveries offshore. The 1983 Atlantic Richfield Company's discovery of natural gas off Hainan was a major boost for Chinese reserves and gave production rates a significant boost. It is possible that further exploration will yield similar results but little has been done so far. As of 1992 only 2.6% of the estimated gas reserves had been proven [OSD p.1-5].

1. Gas Production

Current estimates credit China with 10.0 trillion m^3 in natural gas resources † (13,300 Mtce) including 1.7 trillion m^3 in recoverable reserves ‡ (2,300 Mtce) [CED t.I-1,3]. In 1994 16.97 billion m^3 were recovered, with forty percent of that coming from the Sichuan fields in central China [CED t.II-1]. The Chinese have emphasized oil resource development, rather than gas, and consequently have an gas:oil recovery ratio of 0.107:1 which is very low when compared to the nearly 1:1 ratio in the US and other major oil producing countries [OSD p.II-25]. Gas recovery requires more sophisticated technology and heavier capital investment than oil and therefore has been largely passed over by the Chinese.



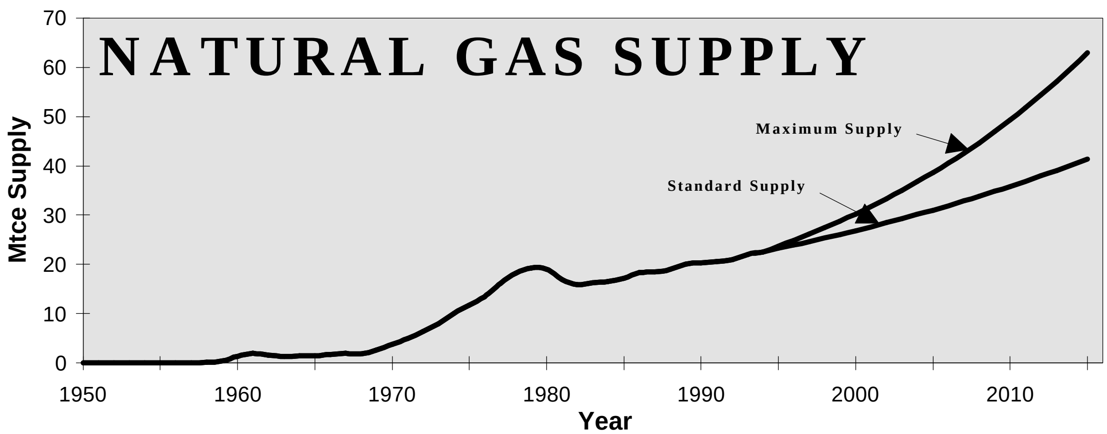
It is possible that the Chinese claims of huge gas reserves offshore may be born out, but to date only one platform has met with any real success. The Atlantic-Richfield Company's (ARCO's) 1983 discovery of natural gas in the Yinggehai Basin off Hainan in the South China Sea led to the development of the only offshore platform (Yacheng 13-1) which seems to be living up to the Chinese promises. In January 1996 ARCO announced that Yacheng 13-1 was ready to enter commercial operation, with an expected output of 7.9 million m^3 daily. The gas will be processed off-shore and fed to the mainland via a 1050 kilometer sub-sea pipeline, the second longest in the world [ED v24 n7]. The Yacheng field has recoverable reserves of 85 million m^3, while the entire Yinggehai basin has an estimated 90 billion m^3 total natural gas resources [ED v24 n7, Owen, p.36].

2. Planned Gas Development

The enormous cost of natural gas projects, about $1 billion per million tons annual capacity, will continue to limit development of this resource [Reuters R040646Z, Jul 95].

† WEC PAP and EAP figures.
‡ Adaptation of BP category "Proved Reserves"

State projections estimate a total of 60 billion m^3 annual production by the year 2000. This would be a 292% increase from the 15.3 billion m^3 1990 total. Declining onshore production may be offset by offshore stations, but many more extraction sites need to be developed if this goal is to be reached. As of 1994 production has increased by less than 11%, making the claimed 202% increase totally unattainable. Further, the 1993-2000 State plan[3] listed only two major gas development projects. The first project calls for onshore reconstruction of the old gas fields in central China's Sichuan province and laying new pipelines. These improvements are expected to yield an additional 2.5 billion m^3 per year. The second project was the development of the Yacheng offshore gas-field, with an expected increase in output of 3.25 billion m^3 per year. The Yacheng platform did begin commercial operation in January '96, but onshore development has been much slower. Even if successful these two projects will increase gas production by only 5.75 billion m^3 (5.35 Btce), leaving China more than 40 billion m^3 short of its goal. This slow development is in complete contradiction to stated production goals, calling into question China's financial, rather than rhetorical commitment to natural gas development.



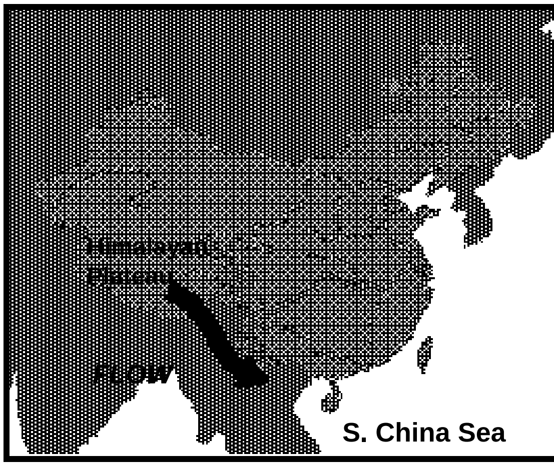
For the Standard scenario, the past decade's average growth of 2.93% was used, while a higher rate of 5% made the Maximum scenario. The actual "high" rate as calculated for natural gas was only 4.48%, but this was increased to match the petroleum industry's maximum growth rate of 5%. This may be interpreted as a continued reliance on petroleum associated fields for gas production, so that as oil production increases, so will natural gas.

E. HYDRO

China has the world's largest hydropower resource. Large rivers originating on the world's highest plateau and the northern edge of the Himalayas in western China have steep gradients and deep valleys, allowing the construction of large hydropower stations.

[3] *The Compilation of Major Technology Introducing Projects of the People's Republic of China from 1993-2000*

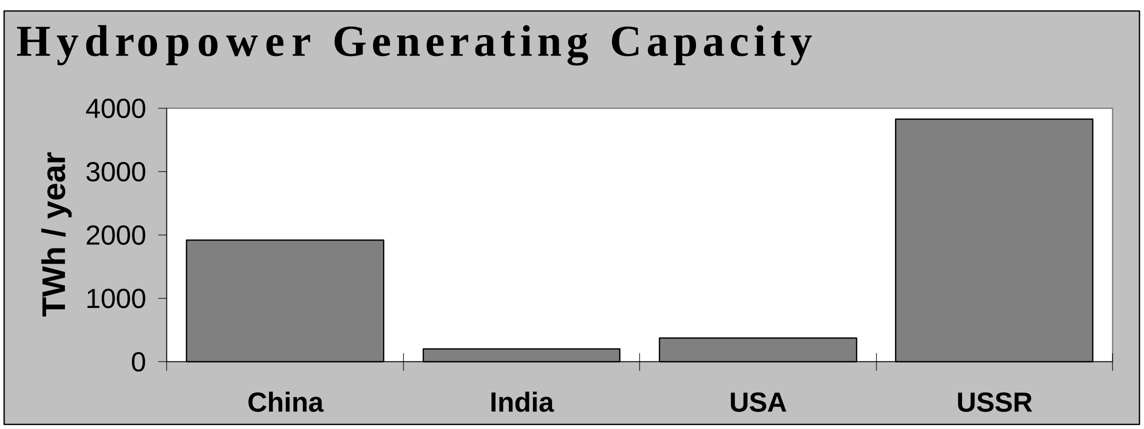
CHINESE RIVER FLOWS



A steep gradient from the Himalayan Plateau to the South China Sea, when combined with heavy rainfall in central China, provides the world's largest potential hydropower generating capacity.

Unfortunately, most of these rivers are small, and unsuitable for powering either industry or urban centers.

Additional monsoon season rainfall in the southwestern regions generates enough water volume to power small scale local hydro plants year round. There are more than 50,000 rivers with drainage basins larger than 100 km^2, and some 1,200 of these have catchments larger than 1,000 km^2. Altogether these rivers carry some 2,640 km^3 of water annually, placing China fifth in the world for water volume [Smil, p.24]. In terms of generating potential China ranks first. The steep gradients and narrow valleys from the western plateau drive the water at relatively high speeds giving China a total of 680 GW of potential generation [4], with 55% or 379 GW of that exploitable (1977-1980 survey data) [OSD p.1-6 & Smil p.24].



Despite these tremendous resources, construction difficulties have prevented the Chinese from making use of many major rivers. The best sites are often in remote and mountainous locations making hydro-plants expensive to build and requiring costly long

[4] Corresponds to WEC category of Exploitable Capability, defined as "the amount of Gross Theoretical Capability that can be exploited within the limits of current technology and under present and expected local economic conditions." Gross Theoretical Capability is "the annual energy potential available in the country if all natural flows were turbined down to sea level or to the water level of the border of the country... with 100 percent efficiency from the machinery driving the water works." Includes output from hydropower stations of all sizes.

distance transmission lines. At present, only 4% of the exploitable hydro resources are being used to generate electrical power (1990) and drought conditions from 1993 to July of 1996 caused a drop in production from these [EinC, p.20].

As with China's other resources, hydropower is not evenly distributed. The southwestern areas dominate with 68% followed by the south-central and central regions. The eastern shore and northeastern industrial areas, where electricity demand is highest hold only 6%.

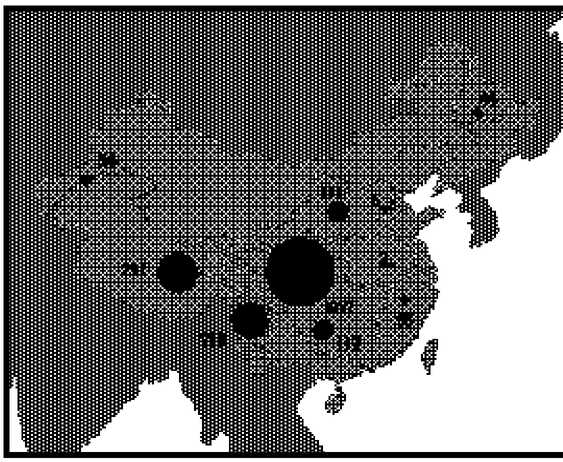
Hydropower has been essential for the generation of electricity in China's rural areas. Small hydro stations power more than 40 local inter-county hydropower grids. In those counties where rural electrification has been tested, 309 started out using hydropower resources and 215 of these have reached a preliminary stage of rural electrification. This growth in installed rural capacity has quadrupled the industrial and agricultural gross output value as well as individual farmer's income in these test regions.

1. Hydro Use

Total annual generating capacity of China's 379 GW exploitable hydro resources amounts to 1,950 TWh. The generating potential is dominated by 33 medium to large sites with a 2 GW or greater capacity, accounting for 50% of the total.

China's is unique in its high percentage of small hydro plants. The steep gradient running from the west to the southeast, combined with heavy seasonal rainfall in central China, generates flow rates sufficiently high that even small rivers can be used for local power generation. Thirty seven percent of the country's hydro capacity comes from plants smaller than 25 MW, and only 41% comes from plants with capacities greater than 250 MW.

CHINESE HYDROPOWER GENERATION



Although runoff grades are steeper in the mountainous south west, it is the heavy rainfall in Central China which is responsible for most of the potential hydropower resources.

Numbers in GW generating capacity
source: *Energy in China's Modernization*, Vaclav Smil

In the past decade, most of the hydro resources developed have been low capacity. Local communities not served by the main power grids built their own small hydro-powered grids. At the end of 1983 there were 76,600 small plants (3,400 with an installed capacity between 500 kW and 12,000 kW, and 73,200 with capacity less than 500 kW) generating 19.9 TWh of electricity [EinC p.20].

2. The Three Gorges Project

In October 1995 construction began on what will become the world's largest hydro-electric generating station. The Chinese are damming a major river, the Yangtze (or *Chang Jian*), with a concrete and steel dam 606 feet high and 7,640 feet wide in the three Gorges region. It will raise water levels 330 feet for 370 miles of river. The dam itself will contain twenty six 500 MW turbines and three deep water locks which will allow heavy shipping to penetrate deep into the mainland.

If it operates as intended, the dam will be able to provide badly needed electricity to energy poor central China. The dam will reduce the seasonal flood risks of the type which claimed more than 300 lives in the spring of 1996. Additionally, the new shipping routes will reduce the need for rail traffic while allowing inland China to develop an industrial base.

However, opponents of the dam claim that none of these thing will happen. Concerns range from the political, including the relocation of 8 million people, to environmental concerns over the loss of cropland and destruction of the gorge's ecosystem. Further, the Yangtze is heavily silted, and some analysts have reported that between siltation [5] reducing the throughput of the dam and seasonal flow variations that the guaranteed generating capacity will be reduced 77% to 3 GW [6] from 13 GW. Other complaints range from general skepticism about the quality of the construction, to fear than an earthquake will send the overhanging cliff face crashing down onto the dam.

Recent floods with death tolls in the thousands and severe property damage on the Yangtze will probably give increased political clout to those in favor of damming the river. In the meantime, despite criticisms, construction continues and the project is expected to be completed in 2009.

3. Planned Development

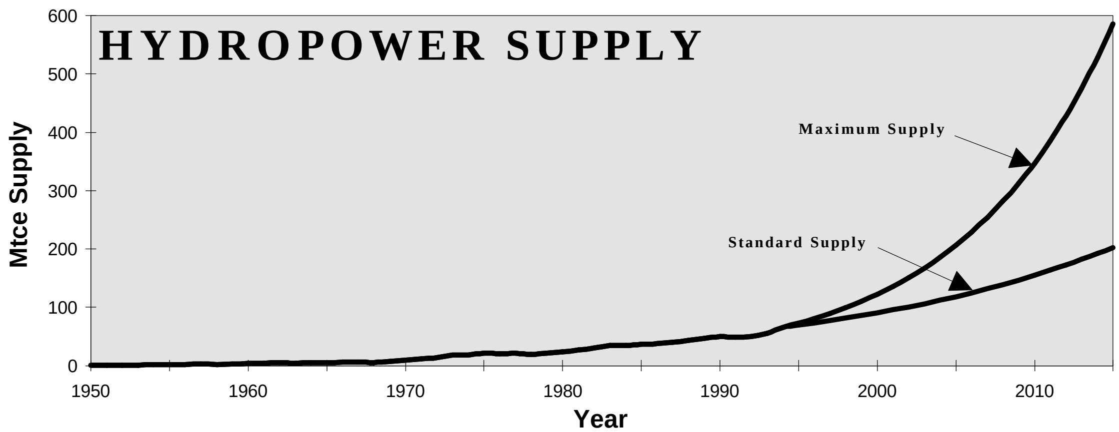
China intends to reach a 300 GW total electrical generating capacity by the year 2000 (adding 117 GW to the 1995 total). In addition to the Three Gorges Project, there are an additional ten proposed hydro projects in Jinsha River totaling 75 GW (feasibility studies

[5] Siltation is the build-up of river sediment (dirt) upstream of the dam. It is possible that the dam will reduce the river's flow rate sufficiently that silt which is currently carried down stream will instead be deposited at the dam.

[6] The source does not offer a rationalization for this low number. However, the 3 GW figure comes from a 38 day field inspection by the Economic Construction Group, at the request of the Sixth National Political Consultative Committee. The investigative team included a former vice minister of the State Planning Commission, the adviser to the State Economic Commission and the Vice Minister of Commerce.

for the first two of these expected early '96) and any number of smaller local projects [IWPDC, p.18-20].

Although the State seems to be emphasizing large scale hydropower projects, the number of smaller local sites continues to grow. It seems that China is willing to let local communities build their own generating plants while the government focuses on supplying power to the growing industrial centers. However, a Siemens spokesman said "we cannot confirm a shift of interest from large scale to smaller projects. Lower total investment or shorter construction time, however, would be in favor of such considerations" [IWPDC, p19].



For the Standard supply scenario, the ten year average growth rate of 5.53% was used, with an 11% rate used for the Maximum supply scenario. This maximum rate would make hydropower the fastest growing energy resource in China. It should be noted, however, that although the Maximum Supply Scenario does provide a definite ceiling, growth is much more likely to be near the Standards scenario level. The Maximum scenario's projection of 585 Mtce electricity generation in the year 2015 is equivalent to 321 GW of generating capacity. This represents 85% of China's 379 GW total exploitable hydropower resources. If the Chinese did somehow manage to install hydropower at the Maximum Supply Scenario rate, growth could only continue for one additional year until 2016 when all of China's exploitable hydropower resources would be in use. As this is unlikely to occur, the Standard scenario growth rate leading to just 29% use of the exploitable resources is a more reasonable projection.

F. BIOMASS

"No other resource is so contrastingly dichotomous as the country's biomass: so critical for everyday rural needs yet so ubiquitously scarce, its potential production so large yet the current sustainable harvest so low" [Smil, p.19]. Biomass supplies 90% of the total energy consumption to some 800 million peasants in China's countryside [EinC, p.21].

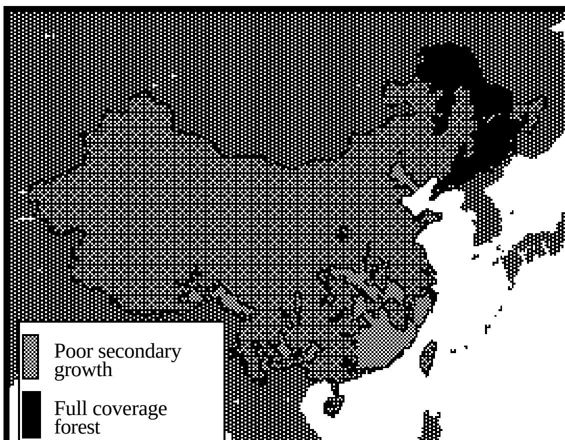
China's phytomass[7] resources measure at 30 billion dry tons (roughly 15 Btce) with a net annual production of no more than 4.3 billion tons [Smil, p.19]. This represents about 3% of the respective global totals, while China covers 6.5% of all dry lands. China's low biomass yields are indicative of a highly stressed ecosystem. China's high altitude dry interior of deserts and poor grasslands, overgrazing of the grasses at lower altitudes, conversion of forest to cropland and general low-quality forest coverage all contribute to the poor biomass productivity.

1. Biomass Production

The vast majority of China's biomass energy comes from biogas (71.9%), reaching over 700 million m^3 per year (651 Mtce). This is followed by crop stalks and straws at 231.8 Mt (14.1%, 127.5 Mtce), firewood at 181.6 Mt (11.6%, 105.3 Mtce), grasses and leaves at 48.0 Mt (1.9%, 17.3 Mtce) and 9.4 Mt of manure (0.5%, 4.5 Mtce) [EinC, p.21]. Most of the biogas production takes place in the south-central regions, where the agricultural byproducts are readily available and temperatures are warm enough to support the use of degassifiers. More than 4.5 million household agricultural degassifiers with capacities of 6 to 10 m^3 are in use, with 300,000 m^3 of large scale digesters and 300 biomass gassifier units operating in rural settings [CED t.II-32].

The reliance on stalks is a direct indication of China's poor forest quality. Total coverage is just 121.6 million hectares (ha), less than 12.7% of China's territory. China has repeatedly tried to implement afforestation plans since 1949, but of the 100 million ha planted, less than one third has survived. The Chinese include low growth density "shelter-belts" as part of their forest total, meaning that approximately 60% of China's so called forested areas are poorly stocked in secondary growth. Even if all of China's woodlands could be categorized as "closed" mature forests (more than 25% ground covered by canopy) this would still rank China no higher than 130th out of the world's 197 odd nations [Smil, p.21].

CHINESE FORESTED AREAS



China has very little full coverage forest, with most forested regions having little undergrowth and poor secondary coverage.

Source: *Energy in China's Modernization*, Vaclav Smil

[7] Phytomass includes all above- and underground parts of trees, shrubs, grasses, crops and aquatic plants.

What forest there is, as with the other natural resources, is not evenly distributed. The majority of the timber is in the southwestern provinces of Yunnan and Sichuan. Southwestern forest can annually sustain 25-30 tons of timber per ha, while those in the northwest can only supply 1-2 tons. Woody phytomass for combustion can be can be gathered from other forests (118 million ha at 600 kg per ha) for a total 71 million tons annually. Unfortunately, actual annual firewood consumption is more than double this rate, making natural forest biomass a very poor choice for China's future energy supply. Demand for new cropland, industrial timber and household fuel has caused a 55% deforestation in Yunnan and 30% in Sichuan.

2. Planned Biomass Production

Since biofuel consumption is associated with rural China, consumption is expected to drop as urbanization progresses. It will, however, be some time before sufficient alternative energy sources are available to the rural population to reduce consumption noticeably. In the interim biomass will remain the dominant rural energy source. Ministry concerns over deforrestation have driven efforts to reduce consumption volume by increasing consumption efficiency. When such efforts are combined with other fuel sources (coal, hydro, etc.,) some strain on the ecology may be reduced. New stove designs have improved efficiency by 40 - 60%, and new biofuel gassifiers are being made with efficiencies up to 70%.

Reforestation plans continue, but so far seem unable to keep pace with the rural consumption. The government encourages everyone to plant three to five fast growing trees each year to offset the losses in forested areas. Original predictions that claimed this plan would generate 85 Mt (49.3 Mtce) annually for consumption were overly optimistic and the plans have met with limited success [EinC, p.21].

Biomass was not included in the energy supply projection because it is not a commercial fuel source, and therefore has no impact on US energy security.

G. SOLAR RADIATION AND WIND

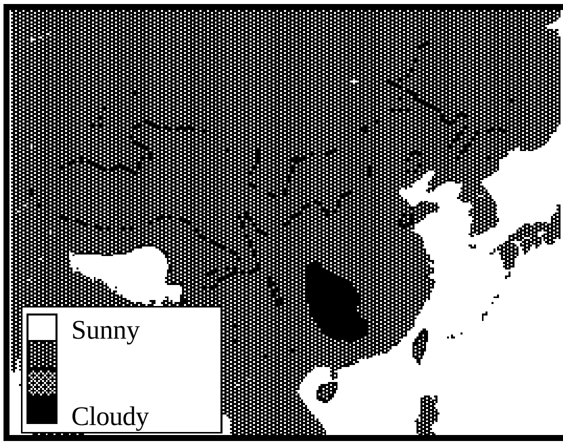
1. Solar Radiation

The first map of China's solar resources became available in 1978, confirming expectations. There is a general NW-SE gradient, with the most intense areas in the Xizang-Qinghai grasslands (eastern Tibet) and the minima in the southern interior. The distribution "makes for a nearly perfect mismatch between the total radiation received at the ground and population density" [Smil, p.10]. The lowest levels of solar radiation are found in China's most densely populated province of Sichuan. Sichuan has so much cloud cover that in its first decade of operation LANDSAT was only able to acquire two clear images of the region. [Smil, p.10].

Sichuan annually receives less solar radiation per year that the US Pacific Northwest or parts of northern Europe, while the whole Xizang-Qinghai plateau receives more than Arizona or New Mexico [Smil, p.10]. Xizang (Tibet) and other western provinces receive annual radiation between 1630 kWh/m^2 and 2320 kWh/m^2. Eastern provinces receive 930 kWh/m^2 to 1860 kWh/m^2, with the slightly better values of 1390-1860 kWh/m^2 in the northeast [EinC, p.24].

The overall contribution of solar radiation to power consumption has been negligible. Total solar array electrical generating capacity had reached only 1.8 MW in 1994 ['95CED, t.II-32]. Survey data indicates that only 200,000 m^2 of solar collectors are in use, mostly in the northeast, and there only for hot water supply in public service facilities [EinC p.25]. Even if the total solar collector area were 100 times larger, all these water heaters could only operate for five to eight months a year for a maximum nationwide fuel savings of 3 million tons of coal [Smil p.13].

CHINESE SOLAR DISTRIBUTION



China's regions of high solar generation potential are in the remote Himalayan Plateau and the western desert, while populated central China in perpetually cloud covered.

Source: *Energy in China's Modernization*, Vaclav Smil

2. Wind

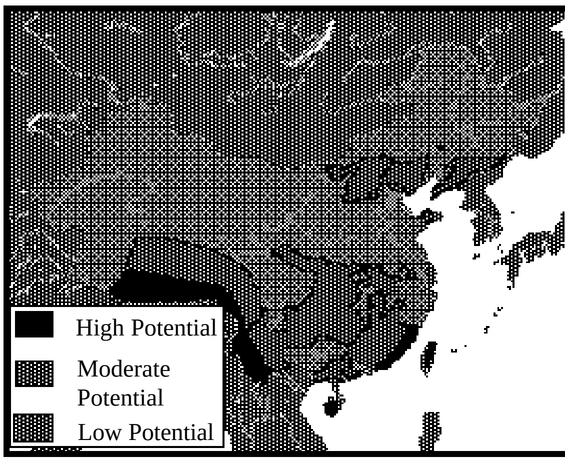
As with solar radiation, most of the windiest places are far from China's heavily populated central provinces. The mountainous areas in the northwest and the northern steppes are by far the windiest, closely followed by the central coastal areas. The densely populated interior, including the Sichuan basin and central Hunan, have calms for at least 30% of the year, up to 50-70% in some places. China's total wind generating capacity is estimated at 1,600 GW (1.6x10^{12} W), with 100 GW in near surface flows. This is of the same order of magnitude as China's hydro potential, but very little of it will be tapped [Smil, p.14]. The greatest potential is in a huge 200,000 km^2 funnel created by the Altay, Kunlun and Tianshan ranges in northwestern Xinjiang. Again, this is a sparsely populated region making exploitation of local wind resources unlikely. The main focus of Chinese wind-power has been in the Nei Mongol grasslands (Inner Mongolia) where winds faster than 3 meters per second are present more than 200 days a year.

H. GEOTHERMAL

China is on the eastern end of the Eurasian tectonic plate, with a compaction region from the India plate to the southwest and a subduction zone with the Philippine plate to the east. With all this activity, it is not surprising that China has large geothermal resources. Most of the capacity is in southern Xizang (Tibet). The simplest indicator of geothermal potential is the distribution of hot springs. A nationwide inventory lists 2,412 separate sources. 279 have temperatures greater than 60ºC and 116 of those are in Xizang (354 total hydro-thermal areas in this province) [EinC, p.23].

The annual heat discharge of China's hot springs totals 111 PJ (3.8 Mtce), with 43% in Xizang, 26% in Yunnan and 4% from Guangdong. Mostly geothermal resources are used as a hot water source for greenhouses, aqua-culture pools and the textile industry. Nationwide geothermal resources suitable for electricity generation are much less than expected given the total heat output. There are a total of only 200 MW in identified resources and an additional 3500 MW in estimated reserves. Full exploitation of this resource would expand electricity generating capacity by less than 5%, and the location of the resources guarantees that few of these will be accessed in the next few decades [Smil, p.17].

CHINESE GEOTHERMAL REGIONS



The Chinese geothermal potential is due to tectonic activity between the East Asian Plate and the India and Philippine plates (Himalayas and southern coast).

Source: *Energy in China's Modernization*, Vaclav Smil

I. URANIUM / NUCLEAR

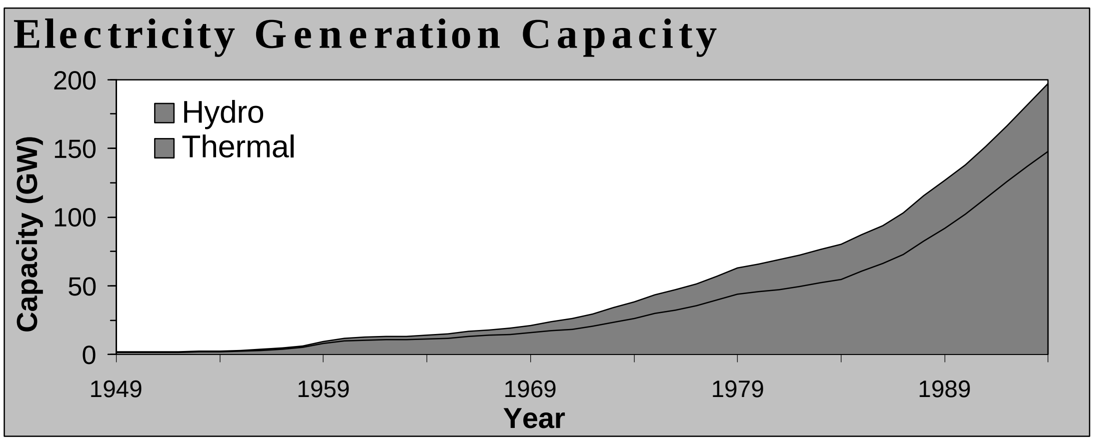
In 1990 China reported uranium resources equivalent to Australia's total reserves, which are the largest in the western world. The actual resource estimates are considered a State secret, while the released Chinese numbers seem to be exaggerated, again making evaluations difficult. If the Chinese category of "Speculative Resources" were to be included, their total would exceed an unlikely 3 million tons U [Owen, p.29]. China's reported uranium resources are concentrated in the northern provinces of Shanxi and Xinjiang, and in the south eastern coastal provinces of Yunnan, Guangxi and Guangdong. Uranium is distributed over 200 known deposits, mostly of the vein type associated with granites and volcanic rocks. Current estimations of recoverable uranium reserves have dropped 49% since 1993 to 51,000 tons U recoverable reserves [CED t.I-1, Puckett, p.9; Owen, p.29].

600 metric tons uranium were mined in 1993, down from 800 tons in ‘92, constituting 1.9% of the world total [‘93 UN, t37]. A mill dedicated to uranium exports is located at Hengyang, south of Chengsha, in Hunan province. The ore capacity of this mill is reported at 725,000 tons/year, yielding about 1000 tons U [Owen, p.29].

E L E C T R I C   P O W E R   P R O D U C T I O N

A. GENERATING CAPACITY

1. Overall

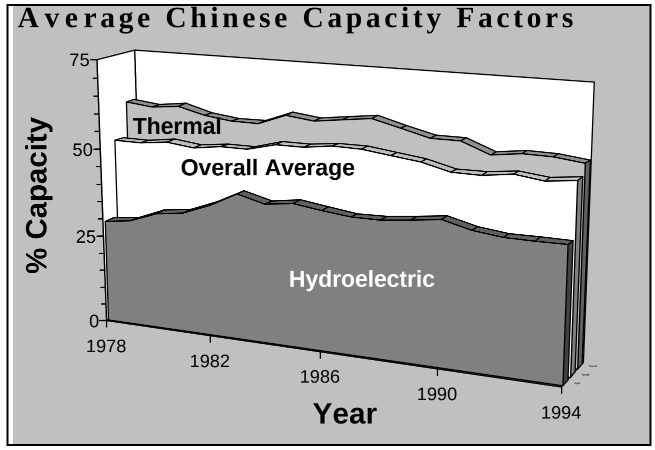


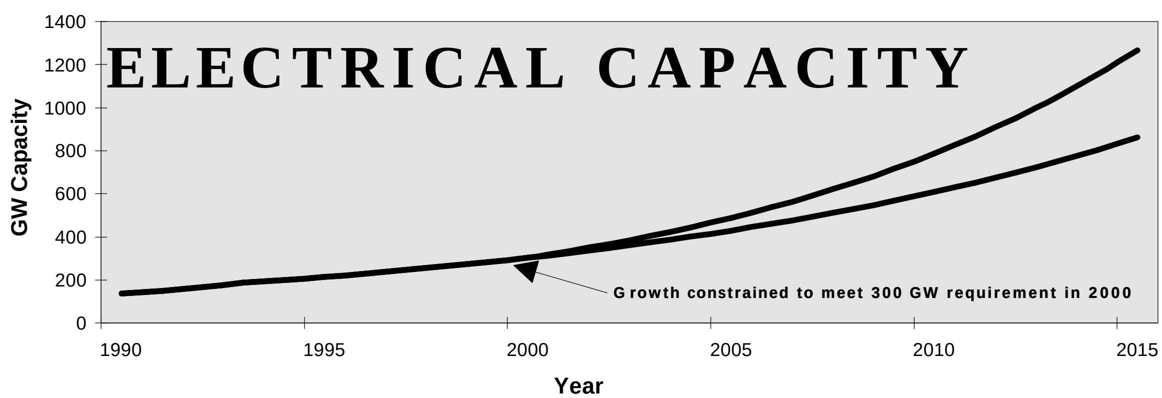
China intends to reach a 300 GW (3×10^{11} watts) generating capacity by the year 2000, adding 117 GW to the 1995 total at a cost of $100 billion. $20 billion is hoped for in assistance from foreign investors [IWPDC, p18]. In 1994 the State Planning Commission targeted 17 projects with a total generating capacity of 20 GW. In addition to the Three Gorges Project (13 GW) the commission intends to add ten hydro projects totaling 75 GW of new capacity, an additional thermally generated capacity of 9.2 GW, and 1.2 GW from the second phase of the Qinshan nuclear plant (totaling 175.2 GW) [IWPDC, p.18 & CMTIP]. If all of these projects are completed by the year 2000, the Chinese will have exceeded their stated goal by 58,200 MW. It must be noted however, that the ten hydro projects which contribute just under 43% of this increase are unlikely to be completed by the deadline as feasibility studies for the first two were not submitted until the end of ‘95 and large hydro- projects have a reputation in China for late completion.

Current generating capacity is 183 GW (1995) [IWPDC p.18], with 74% from thermal plants and the remaining 26% coming mostly from hydroelectric plants [‘92 UN ESY table

32]. Alternative power sources such as wind turbine generators, solar converters and geothermal plants produce so little energy as to be negligible.

China's electrical problems include frequent brown-outs and complete power failures. University students in northeastern China bring candles for reading light when going to the library. Rural homes stock up non-electrical light sources as a matter of course. Industries frequently purchase their own diesel generators as backups for the inevitable power outages. These problems are symptoms indicating that the increase in capacity has lagged demand. Capacity factors on major grids average 0.60 or higher, with the Eastern China Grid running at almost 0.70 (US capacity is 0.42). These are equivalent to load factors greater than 90% (90.8% load for 0.56 average capacity on Central China Grid, 1991) [CED, t.II-22]. Backup capacity is inadequate and as demand increases, especially in the developing free trade and industrial areas, electricity supply will need to increase dramatically.





Both the Standard and Maximum Supply scenarios for electrical generation capacity were scaled to meet the anticipated 300 GW capacity in the year 2000. This required a 7.2% annual growth rate. For the Standard scenario this growth rate was maintained, while for the maximum growth rate it was increased to 10%, representing an average of the best growth rates attained between 1985 and 1995.

2. Fossil Fuels for Electricity Generation

Thermal plants produced 75.6% of China's total electricity, and consumed upwards of 243 Mtce of fossil fuels in 1995 ['92 UN ESY t.32 & OSD p.II-27]. Of this consumption 86.6% was coal, 11.5% was petroleum and 0.7% came from natural gas (1989) [OSD p.II-27]. Thermal generation accounts for an increasing portion of total electricity generation. The growth rate of total generation from 1990 to 1993 was 9.3%, while the growth rate for thermal generation was 10.2% [CED, t.II-17].

Chinese thermal plants tend to be small, with only 15 having capacities greater than 1 GW and with the majority being less than 100 MW [OSD p.II-27]. Inefficient low and medium pressure turbines compose about 20% of the thermal capacity, putting the conversion efficiency at 27%. The Chinese consumption fraction measured 0.431 kgce/kWh, 14% more inefficient than the US figure. If pollution controls were to be installed on these plants efficiency would drop even further.

Most of China's thermal capacity is near the load centers in the northeast and eastern coastal areas. Many newer plants have been built at coal mine mouths to reduce the volume of coal needing rail transport. China has built no oil burning thermal plants in the past decade, saving petroleum for other domestic uses and export.

3. Hydroelectric Generation

Installed hydroelectric capacity had reached 50 GW in 1994, representing 18% of the total electricity generation and 13% of the recoverable hydro reserves. Hydroelectric capacity has grown steadily, averaging 7.73% per annum since 1986.

There are more than 150,000 small hydro plants in rural China. Two thirds have generating capacities less than 500 kW, and the remainder have capacities between 500 and 12,000 kW [EinC p.20]. At the end of 1994 a little over 48,000 of these with a total installed capacity of 15,050 MW had been interconnected, forming 40 local inter-county power grids in rural China.

It is likely that hydroelectric power will continue to be the generating source of choice in many southern rural areas where coal reserves are minimal. However, even if the large scale projects like the Three Gorges Project[8] (TGP) are completed and operate at capacity, hydroelectric generation will be able to supply only 18% of the anticipated power demand.

4. Nuclear Generation

China has two nuclear power plants on line with a 2.1 GW total capacity. The first is a domestically designed 300 MW pressurized water reactor (PWR) near Shanghai, which is currently receiving a two reactor upgrade from South Korean firms. The only other

[8] The Three gorges Project is a large Hydro-electric power generating station under construction on the Yangtze River in central China. It will house twenty six 500 MW turbines and include three deep-water locks for to allow the development of inland waterway shipping capacity.

operating plant is another PWR with two 900 MW French built reactors which supply power to Hong Kong from Daya Bay, both went on line in the spring of 1994.

Nuclear power is very appealing to the Chinese government in that it offers power independent of coal. The Chinese seem willing to accept the limitations of an open fuel cycle and decommissioning problems for the environmental benefits of no ash and sulfur emissions. On a cost basis nuclear plants are appealing for their reduced infrastructure costs, while expanded nuclear fuel use would free up rail-freight capacity and increase the amount of coal available for export. The all Chinese Quinshan plant consumes only 10 metric tons of fuel annually, and the Daya Bay plant 30 metric tons. Coal burning plants of the same capacity would consume more than 1 and 3 million metric tons respectively of standard coal. This is the equivalent of two versus tens of thousands of railway car loads. Also, a thermal plant requires specialized railroads, piers and other transport facilities representing a huge investment in support infrastructure.

China will add 6,600 MW to current capacity by 2004 through upgrades of the two existing plants and construction of two additional plants. The first new plant will a PWR in northeastern China's Liaoning Province, and the second an additional Daya Bay plant to supply power not to Hong Kong this time, but to Guangdong province and China proper. The new plants will be built with foreign reactor parts. The second Daya Bay plant will have two 985 MW PWRs built by Framatome, while the Liaoning station will use two 1,000 MW Russian reactors. The new plants are expected to go on line in 2003 and 2004 respectively. The upgrades of the two on line plants will also use western suppliers. The Quinshan plant, which had contracted with a South Korean firm for the new reactor vessels (a deal which fell through after China was unable to obtain suitable financing), will now obtain parts from Framatome (steam supply and fuel assembly components) and Westinghouse (turbine generators and possibly the reactor vessels) for major components.

There is talk by China of increasing its nuclear capacity by nearly 2000% to 40-50 GW by 2020, but there is some doubt as to China's ability to supply fuel for such a large number of conventional reactors. If the 40 GW goal is reached it is likely that the Chinese would require a foreign uranium supply, but experts suspect that this goal is unreasonable. More than ten provinces are conducting feasibility studies for nuclear plant construction, but it is unlikely that all will be approved. China lacks the necessary investment funds, and the initial lump-sum required to start a nuclear plant is much more than that for a thermal plant, even with the reduced support infrastructure costs. Additionally, the World Bank considers nuclear plants too dangerous for developing nations and does not provide financing for nuclear projects.

4-a. Nuclear Waste and Fuel Reprocessing

As of 1991, all nuclear waste was stored in temporary drums. Construction of permanent waste dumps in eastern and northwestern China is still underway. The eastern dump is intended to receive the waste from the Qinshan and Daya Bay plants, while the northwestern facility will handle waste from China's nuclear weapons testing area.

China has yet to build a commercial fuel reprocessing plant, but plans have been submitted for the construction of a Purex [9] plant in western Xinjiang Province. The plan calls for spent fuel to be transported to the reprocessing plant after 3 to 5 years storage in reactor site pools. Once the uranium and plutonium have been recovered, waste will be sealed in cement for underground burial. The proposed Purex reprocessor would be able to handle more than 30,000 kg of PWR spent fuel annually.

5. Alternate Source Generation

China has experimented with electricity generation from alternate sources on a small scale. Total generating capacity from these sources is less than 25 MW, but they may be relevant for future planning. It seems unrealistic that any non-conventional source will become a primary power supplier, even on a local basis, but their potential as backup to relieve grid capacity overload should not be overlooked.

China has seven geothermal electrical power generation stations. Six have capacities below 1 kW, and four of these are inefficient binary installations which use hot water (67ºC-91ºC) to vaporize a working medium (butane or chloroethane) with a lower boiling point. The Yangbajang station is the only medium sized wet-steam plant in operation with three 3 MW units and one 1 MW unit on line. Unfortunately the inefficiency of these turbines limits production capacity, and the 1983 geothermal capacity of 8.4 MW has not been improved upon, although Ministry figures for the theoretical potential range as high as 25 MW. In either case, this is two orders of magnitude below US capability, representing less that half a percent of the worldwide geothermal electrical power production.

In 1990 China had a total of 122,000 wind turbine generators (WTGs) installed, bringing the wind generated capacity to 12.91 MW. China's first wind farm of three turbines was commissioned in 1986 on the eastern sea-coast of Shandong province. By the end of 1993, this farm had grown into 92 grid connected WTGs with a total installed capacity of 11,631 kW. At Nan'ao Island in Guangdong, a 1.68 MW wind farm generated 25% of the district's 16.8 million kWh [Yongfen, Pengfei]. This would indicate that wind resources can and should be utilized where possible to support local power grids.

[9] The Purex system is a fuel reprocessing technique which separates plutonium and uranium from reactor fission products.

A. INVESTMENT, CONSTRUCTION COSTS & INFRASTRUCTURE

Detailing Chinese investment is difficult. There are differences between reported and actual investment, inconsistencies in coverage and changes in the definition of "investment". However, where the Chinese spend their money is still the most significant indicator of Chinese energy policy priorities.

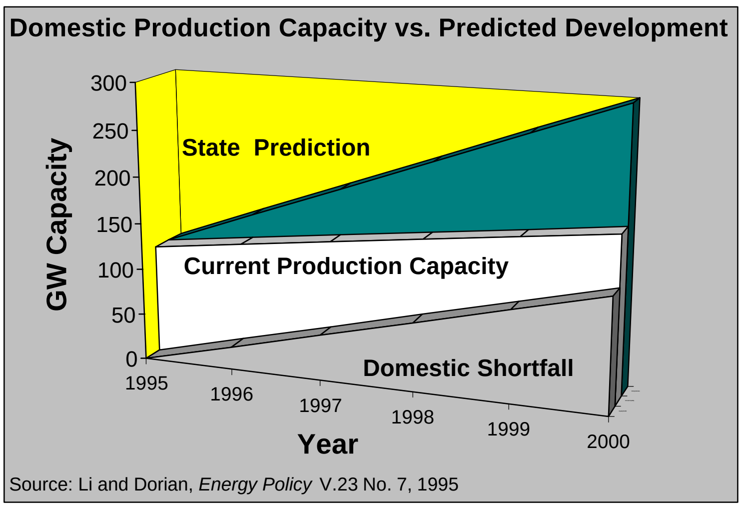
The Chinese government has spent an ever increasing portion of its available capital on energy related projects. Energy related capital investment has been growing an average of 3.9% annually between 1980 and 1990. In 1993 the State spent a total of ¥765.8 billion, 60% on capital construction, 20% on energy industry investments and the remaining 20% on other projects [CED, t.III-1]. Figures for 1995 place total investment in fixed assets at ¥1.7 trillion, with 53% going to infrastructure. Of the ¥84.67 billion spent on energy industry investments, 66%, or ¥55.83 billion went towards capital construction (power plants, sub-stations, grids, etc.,) while 15% or ¥12.51 billion went towards technical upgrades (replacing old equipment) [CED II-16, II-18, III-1].

With the 1995 total generating capacity at 183 GW, extrapolation of past trends using energy investment in capital construction and the annual increase in total energy capacity indicates that to reach the stated goal of 300 GW total capacity by the year 2000 would require ¥611 billion ($72 bn.), or ¥122 billion ($14.4) annually for the next five years. This agrees closely with Chinese estimates as quoted by CS First Boston Bank at $14-15 billion. These figures do not include the costs of replacing antiquated equipment such as generators, transmission lines and sub-stations. The Chinese estimate total costs including upgrades and maintenance to reach $100 billion [IWPDC, p.18].

1. Turbine Manufacturing Capability

Most Chinese turbines have capacities less than 100 MW, but the Chinese turbine industry is capable of manufacturing turbines with capacities up to 300 MW. There are fewer than a dozen 600 MW systems in operation, and these are almost entirely imported. Of the additional fifty high capacity turbines being installed in the next seven to eight years almost all will be imports. The Chinese do have a few domestically built 600 MW turbines in trial operation but it will be several years before they are capable of manufacturing these in any relevant quantity. To accelerate their domestic power system manufacturing capabilities the Chinese have engaged in joint ventures with ABB, GEC Alsthom, Mitsubishi, Hitachi, Toshiba, Westinghouse and GE. Additionally, in the past two years the Chinese have entered into joint ventures with Japanese and US companies to acquire technology for the manufacture of 900 MW units. As the Chinese gain expertise and familiarity with the technology, a greater portion of the installed large capacity systems will be manufactured domestically.

As stated previously, China intends to bring its 1994 199 GW generating capacity up to 300 GW by the year 2000. This will be done by not just by adding new capacity, but also from increases in efficiency, though refits and upgrading old technology. Unfortunately for China, the domestic turbine manufacturers, operated by the Ministry of Machinery Industry (MMI), are unable to accomplish this unaided. MMI's current production capacity is only 9 GW per year. Even if all other potential turbine manufacturers in China are included annual production only reaches 12 GW [Stinton]. This is considerably short of the necessary 17 GW per year in new capacity, and even shorter of the total 36.6 GW per year including upgrades and refits. Even an optimistic appraisal of Chinese production will be 29 GW short in new capacity, and since at least some refits will be required China may fall as far as 147 GW short of the 300 GW goal. Without purchasing foreign equipment, China is unable to meet the demands for electricity, and would severely inhibit growth in its electricity hungry new high tech industries. China would fall so far behind that it would take ten years to make up the difference.



However, in recent years China has bought up to 20% of its generating capacity from foreign suppliers. To effect a full refit and fill the 36.6 GW maximum annual requirement, the Chinese would have to purchase 24 GW of foreign equipment annually at a cost of $19 billion. This is not likely to happen. A more estimate would be the purchase of 5 GW to 10 GW in foreign equipment. Which in turn implies annual costs of $4 to $8 billion [10], or a total of $24 to $48 billion before the year 2000.

2. Power Investment Costs

Many foreign analysts are quoting the Chinese new electricity generation capacity as costing $1,000 per installed kW. Calculations from installed capacity and investment in energy industry capital construction yield a lower figure of $610 per kW, which agrees

[10] Assumes a cost of $800 per kW for foreign suppplied equipment

with Ministry of Electric Power Industry (MOEP) and other DOE study results[11] of $600 - $720 per kW for thermal plant generation [Stinton].

Prices for alternate sources of energy are slightly more expensive. MOEP estimates place hydropower generation at ¥7,000/kW ($840/kW) including heat generation and distribution for large scale projects and ¥12,000 ($1,450/kW) for those on a smaller scale. Wind turbine generation, including associated costs, is placed at ¥10,000/kWe ($1,200/kW). The limited extent of China's current nuclear capacity has made nuclear the most expensive, with current costs of $2,000/kW. Industry experts believe that with expansion of the program costs will drop below the typical value of $1,700/kW to $1,200/kW by 2020 [Stinton].

3. Power Plant Operations, Upgrade and Maintenance Costs

China's low labor, fuel and equipment costs give it a comparably low operational rate. Many nuclear power advocates claim that nuclear power is competitive with coal-fired plants (¥10,210/kW for nuclear vs. ¥8,331/kW for coal) but studies indicate that while initial construction costs may be similar in China for thermal and nuclear plants, the operational and maintenance costs for nuclear plants will be at least 21% higher [Zongxin, pp. 780-2, 1995]. In the US, nuclear plants are slightly more expensive to build but less expensive to maintain than their fossil fuel equivalents.

Additional costs will be incurred as plants upgrade their environmental controls. Most fossil fuel fired plants utilize in-stack particulate filters, and many of the larger new plants also have electrostatic precipitators (require frequent maintenance but otherwise work very well and with high efficiency). Recently enacted air quality legislation makes "it more likely that new plants will at least include space for future installation of" flue gas desulfurization (FGD) equipment [Stinton]. Multilateral agency funded projects now require FGD installation, and a very few Chinese plants already have them installed.

4. Power Plant Financing & "Doing Business in China"

China needs foreign investments to finance its electrical power development, but so far has been unable to negotiate more than a few large projects. In fact recent trade policies have made foreign companies working in all markets rethink doing business with China. Uncomfortable with the thought of loosing market share and profits to "outsiders", China is using coercive tactics to make foreign companies pay for access to it's fast growing markets with technology transfer. The telecommunications Minister criticized Motorola saying the company had "earned quite a lot of money in the mobile telephone market in China. It's high time for them to transfer some technology" [WSJ, Dec.19, '95 p.A12]. Under such pressure from the Chinese, and fear of losing out to competitors like the French conglomerate Alcatel, Motorola agreed to build a $720 million semiconductor plant with full technology transfer [WSJ, Jan. 15, '96, p.A9]. The Chinese are very

[11] *A Review of Power Plant Costs in China*, Jonathan E. Stinton ,LBNL Energy Analysis Program, draft copy, December 1995

interested in such ventures not only because they eventually hope to export the high-tech products but because the central government still controls segments of the economy which in other countries are purely private. Many state run enterprises have been forced to shut down production lines as a result of the measures taken by the government to curb inflation [WSJ, Jan. 2 '96]. With state enterprises failing as foreign companies take increasing portions of the market share, Beijing is insisting on technology transfer as a means to keep its own industries alive.

As a result, most foreign companies conducted investment at the local level on low cost projects (less than $30 million or ¥ 255 million) which do not require central government approval. However, lately even this sort of investment has cooled with the spread of rumors of unofficial caps on rates of return.

In seeking loans for power and industry development, China amassed $100 billion in debt as of 1994. In the past 15 years China has used $14.5 billion in foreign funds to complete 64 power projects totaling 10.7 GW, with more than an additional $1 billion committed to projects for 1995 [IPWDC, p.18; Stinton p.3]. The largest contributors were the World and Asian Development Banks, who earmarked most of the monies for hydroelectric projects. These numbers are insignificant when compared to the cost of meeting the 300 GW goal. China's domestic manufacturing will see minimum shortfall of 43 GW in new capacity, and up to 123 GW in overall deficit [12]. Using a modest $700/kW for imported generation capacity, China will require $30 billion to $86 billion (¥ 255 to ¥ 732 bn.) in foreign supplied electrical power generation equipment[13].

Large companies have been trying to establish joint venture or direct stake agreements but have been unable to persuade the Chinese. In 1994 Goldman Sachs went so far as to pull out of a major funding deal for power plants in Shandong province when Beijing imposed a 12% ceiling as the return on equity. At the same time Beijing passed a rule preventing foreign investors from holding a majority stake in large power plants or equipment manufacturing ventures. A spokesman for Siemens recently commented that "conflicting information [from Chinese sources] and changing regulations have hampered investments in Chinese [energy] projects" [IWPDC p.19].

5. Infrastructure Construction

For the purposes of this report energy sector infrastructure consists of the physical apparatus required to transport and distribute resources for both consumption and trade, as well as the mechanisms for power distribution such as electricity grids, sub-stations and transmission lines. Information on total infrastructure costs and investments is difficult to obtain as the Chinese do not organize their data in this fashion. However, trends can be observed and estimates based on cost of existing infrastructure and planned expansion can be made.

[12] See: Cost Finance & Trade, A.1. Turbine Manufacturing Capability

[13] This cost depends on whether China engages in no refits ($30 bn.) or in complete refits ($86 bn.). Refits might be delayed to stretch cost schedule out.

China's 1994 investments in fixed assets increased a dramatic 28% to a total of ¥ 1.59 trillion ($274 bn). Most of this investment went into construction of freight transportation resources such as railways and port facilities and into electrical power distribution systems. Total freight volume increased 5.8% to 11.8 billion tons. The volume of rail freight was 1.25 trillion tons/km, and the volume handled by major coastal ports was 730 million tons.

5-a. Power-lines

Of the $5.5 billion invested in Chinese power industry capital construction in 1990, $808 million was spent on power distribution. Although in straight numbers this was an all time high, it represented a share of only 14.7%, down from an average of 21% in the preceding five years [CED III-5a].

5-b. Railroads

With coal fired plants comprising the majority of China's electrical production capacity, the ability to transport coal from the mines to the generation centers becomes a major concern. The 653.2 Mt of coal shipped annually accounts for 42% of China's total rail freight transportation capacity, and 50-70% of all rail traffic from Beijing to Guangdong, Shenyang, and Shanghai ['95 CED t.II-30]. In the past, lack of rail capacity forced mines to abandon coal at the pit mouths while industries which required coal had to cut back on production for a lack of it. Railway lines are vital to the economic growth of remote areas like western Xinjiang, and again a lack of transport capacity has slowed the development of the region, exploitation of its natural resources and transportation of those resources to the consumption centers in the east.

Consequently China is adding to its rail capacity at a furious rate. China laid a national record 3,346 km of railways in 1995 at a cost of ¥ 33.2 billion[14] ($3.9 bn. total, at ¥ 9.7 million/ km)[15]. 1994 freight handling capacity reached 1.57 billion tons, 11 million tons more than scheduled, with an additional 1.89 billion passengers carried. Ten key rail construction projects are either underway or recently completed, including the 2,538 km Beijing-Kowloon line which opened in February of 1996, and a 1,622 km double track from Lanzhou to Xinjiang (opened September '95) as well as a number of other single and double lines under 1,000 km. In total, some 6,000 km of new railway line and 3,500 km of double track lines were completed between 1990 and 1995, with 2,600 km electrified.

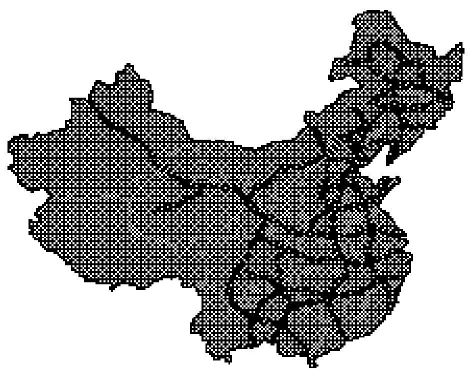
Chinese rail freight capacity is overloaded. Twenty million tons of coal is forced into stockpiles annually for lack of transport. A few mines have stockpiles of over 80 Mtons waiting to be shipped. Lately, new power plants have been constructed literally at coal mines to reduce the need for long distance freight capacity. However demand at remote sites has still caused an increase in average freight distances to over 400 km from the 1990

[14] 1994 Yuan (¥)
[15] In 1996 currency: ¥9.7 million/km = $1.1 million/km; or 103 km/ billion ¥ = 874 km/billion US$

average of 270 km [*Energy Policy* 22(7), p.613]. In 1994 railways handled 659 Mtons of coal, 42% of China's total freight capacity.

It is unlikely that the 1994 railway development rate can be maintained since a significant fraction of that came from doubling single track lines and improving existing track. However, the Chinese have demonstrated that they are capable of generating 3,000 - 4,000 km of new track annually at a cost of ¥ 29-39 billion ($3.4-4.6 bn.). In remote areas the cost per kilometer may increase by as much as 21%[16].

CHINESE RAIL SYSTEMS



China's rail system is under developed. North to south freight traffic is saturated, forcing coal users in southern China to use low grade local coal, instead of the high grade coal from northern mines. Also, minimal rail capacity in the western desert is hampering the development of oil extraction in that region.

In the State plan for 1996-2000 China allocates ¥ 330 billion ($39 bn.) for railways, including ¥ 250 billion ($24 bn.) for track construction and ¥ 80 billion ($960 million) for engines and trains. 10,000 km of new track is scheduled to be lain by the turn of the century.

5-c. Sea-Ports and Shipping Capacity

Increased development in industry, a growing GNP and demand for the transportation of resources has caused a surge in port shipping volumes. The Bohai Sea's shipping industry has seen tremendous growth in the past decade, with more to come. It is the main shipping region, especially for export and transport of coal by sea to south-eastern China. The major industrial and production areas of land-locked Shanxi, Beijing, Inner Mongolia and the northeastern province of Liaoning all ship through the Bohai Sea. The local economy accounts for one third of China's freight transport, one fourth of postal communications and more than half of all coastal shipping to foreign customers [*China Today*, Feb. '95 pp.43-44]. The area is also China's largest transit base for grain, crude oil and coal. In fact coal makes up 20% of all freight moved by water [EinC p.17].

Planned construction includes a special coal quay at Qinhuangdao Harbor with three deep water berths and a 30 Mton capacity, 6 more berths at Dayaowan Harbor for an additional 3.1 Mtons capacity, five deep water berths at Dailan Harbor with 2 Mtons capacity, an

[16] Estimated price increase calculated from difference in figures for 1994 total rail construction and cost (converted to '96 ¥) and track length versus cost for the new Beijing-Kowloon line.

extension of Dandong Port for an additional 950 thousand tons, six berths at Yantai (Shandong province) for 3.4 Mtons, six sundry goods berths in a new wharf in Qinghangdao for 3 Mtons, 2.1 Mtons in sundry goods berths at Lianyungang Harbor and an additional 25 thousand tons of coal capacity at Shanghai. This totals 44.6 Mtons of increased capacity by the year 2000 [TCMTIP-PRC'93-'00].

5-d. Coal Extraction

The costs of the projected capacity increase to 1400 Mtons annual coal production by 2000, including transportation and infrastructure improvements are ¥621 per annual ton ($73). The projected 295 Mtons per year increase in capacity from Ministry mines will require ¥21.4 billion per year. Investment in coal extraction and processing in 1989 totaled ¥27.6 billion (1995 ¥, excluding privately owned mines) so financially this goal is certainly achievable [CED III-4; OSD pII-21].

5-e. Oil Pipelines

Most oil is transported by pipeline. Where pipelines are unavailable, railway lines substitute. There is a total of 10,000 km of oil bearing pipelines from drilling fields to refineries. To alleviate strain on the rail system a 1,000 km pipeline from the Tarim basin in Xinjiang to the refineries in Sichuan is currently under construction is at a cost of ¥5 billion. Since it is unlikely that the oil-fields in the northeast will see much increase in production, it is reasonable to assume that in the near future most new pipeline construction will be onshore from western Xinjiang to central China. Using the Sichuan-Tarim pipeline as a guideline, we may reasonably assume a cost of ¥5 million/km. As the western region becomes more developed the expense will decrease, but that development will be slow. If China pursues off-shore drilling, pipelines from these sources are expected to be considerably more expensive.

B. IMPORTS & EXPORTS

In the context of total world energy trade, China's current exports are of little significance. In 1993 China imported only 35.6 Mtce in energy resources while exporting 53.0 Mtce. Most of the export volume was oil, 19.4 Mtons (27.8 Mtce), and hard coal, 18 Mtons.

439 Mtons of coal were traded internationally in 1993 [17] ['93 UN, t6]. China accounted for only 4% of the trade volume while contributing 33% to global production ['93 UN, t6]. If domestic consumption of coal can be reduced, China has the potential to become a major coal exporter. Currently, the high ash content and lack of washing facilities make Chinese coal less attractive than its competition.

[17] World import total, exports not included to avoid double counting coal volume; 1993 UN Energy Statistics Yearbook: Table 6

Japan was the largest single buyer of Chinese coal in 1993, purchasing 6.2 Mtons, but in 1992 Japan bought no Chinese coal at all (substituting with supply from the Russian Federation). This is perhaps due to the Japanese industrial need for high grade washed coal. Upwards of 55% of the Japanese imports are low ash and sulfur content washed coal from Australia, with Canada and the United States as the next largest contributors [‘93 UN, t7]. The lack of coal washing facilities has prevented China from contributing more than 10% to the Japanese imports. If the Chinese wish to expand their role in the world coal market, they will need to upgrade their washing capacity.

There is some concern over China’s ability to consistently deliver coal for export. Domestic consumption is so high and freight handling systems are so overloaded that a physical inability to deliver in large volumes is considered likely. The recent improvements in rail capacity on east-west lines from Shanxi to ports on the Bohai Sea and seaport freight capacity improvements may reduce bottlenecks but an ability to export on a large scale has not yet been tested.

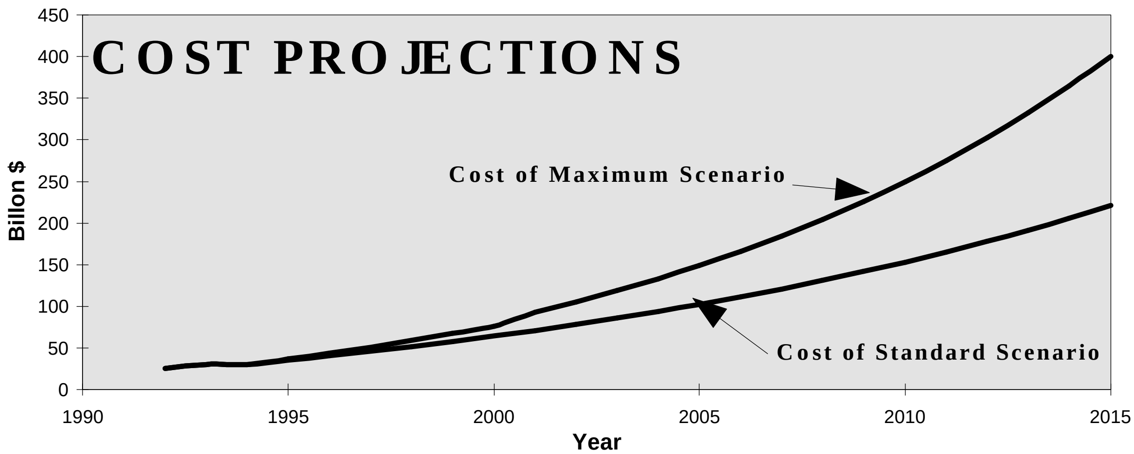
China’s oil trade is one area of immediate concern. In 1994 China produced 147.7 Mtons of crude, while consuming 153.3 Mtons. China imported 13 Mtons and exported 7.4 Mtons. Of the imported crude, 39% came from Indonesia, with the next largest reported fractions at 3% from Libya, 2% from the United Arab Emirates, and with Saudi Arabia and Iran contributing 1.6% and 1% respectively [‘93 UN t15]. Some analysts are concerned that with automobile ownership on the rise, China may soon become a major buyer of mid-eastern oil, causing prices to climb and creating the potential for conflicts with US energy interests. However, although the anticipated oil imports will be large for China, they will be small compared to the expected consumption increases in the US and Europe. The effect on world energy markets will be minimal. In the past, China has exported quantities of its own heavy crude to help fund domestic projects and it is likely that should Chinese oil production increase this trend will continue.

China’s 1993 uranium production fell 25% from 800 to 600 metric tons [’93 UN t37]. Since 1985, when domestic uranium first became available for export, China has sold it. The first shipment of 50 tons went to West Germany in 1985. As of 1990 China was the main supplier for most of that country’s annual 400 tons U demand. To place that in perspective, 1993 statistics put China’s uranium sales at less than 1.5% of the global total. Additionally, rumors of clandestine uranium sales have been reported in the western press. China is suspected of having sold enriched uranium to several countries developing nuclear weapons programs such as Iraq, Pakistan and South Africa as well as having sold heavy water (necessary for reactors using natural uranium) to Argentina and India. However, even if true, while these sales may have tremendous political significance they do not affect trade or US energy security. With its limited mining facilities, 725,000 tons/year mill capacity and plans for up to ten additional domestic nuclear reactors China is unable to trade nuclear fuel products on any great scale.

C. TOTAL COSTS TO SUPPLY ENERGY RESOURCES & ELECTRICITY

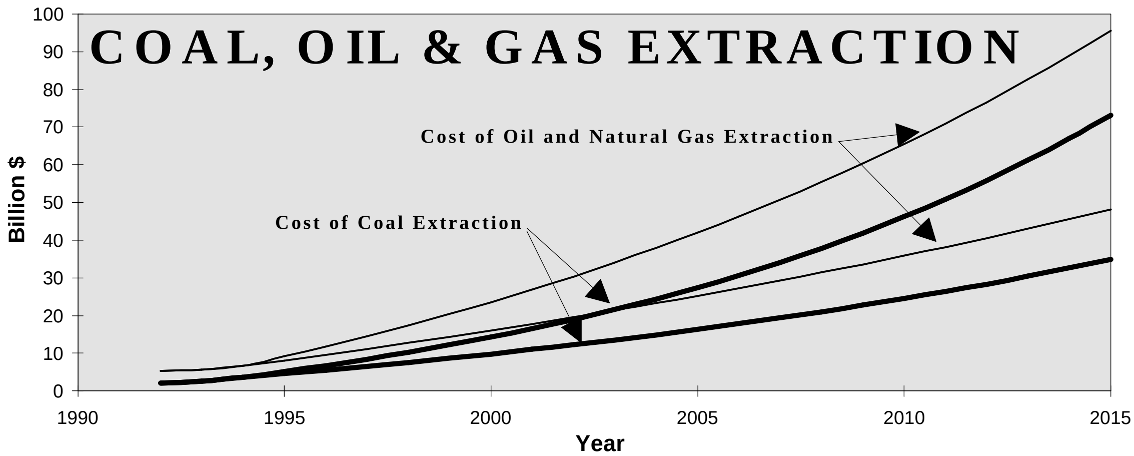
Both the stated energy goals and our predictions for resource supply are within China's financial grasp. In 1995, the total expenses for energy resource extraction, installing new electrical generating capacity and actual electricity generation were approximately $36 billion, or 5.6% of the $643 billion Chinese GDP.

To reach the 300 GW total generating capacity by the year 2000, China will spend at least $12 billion on new electrical generation capacity, with an additional $60 billion spent on energy infrastructure and $100 billion spent on refits and upgrades[18]. These figures imply a total expenditure of $172 billion, or $34.4 billion (¥ 292 billion) spent annually for the next five years on electricity. In 1995 $12.5 billion was spent on electricity generation, with an additional $10 billion spent on new capacity and refits. This means that the Chinese need to spend ever increasing amounts to meet their goals and sustain past growth rates.

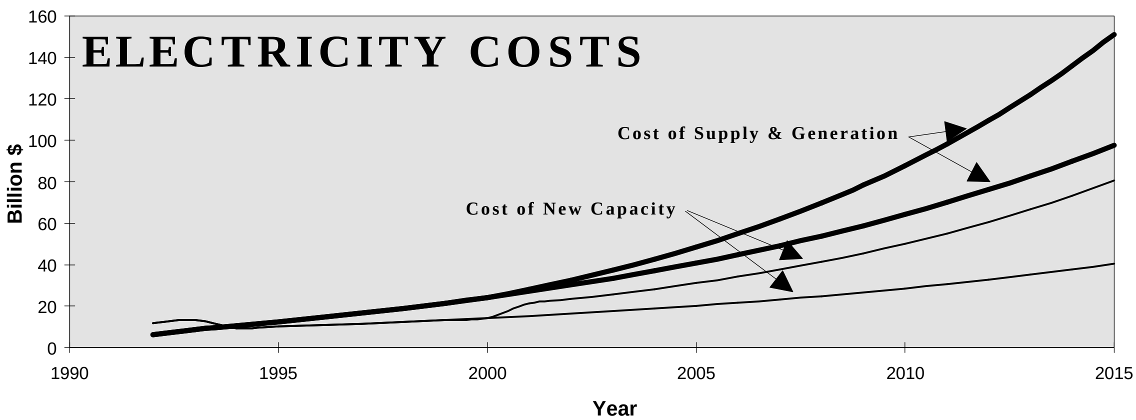


By the year 2000, coal extraction will cost between $10 and $14 billion depending on the production rate (*Standard* or *Maximum Supply Scenario*). Actual electricity generation will cost $24 billion, with an additional $14 billion spent on increased generation capacity. Meanwhile oil and natural gas extraction will cost between $16 and $23 billion, for total costs in the year 2000 of $64 to $75 billion (double the 1995 expenditure), again depending on production rates.

[18] See preceding sections 'Turbine Manufacture" and "Power Investment Costs" for more details.



By 2015 these costs will have again increased significantly, with $35 to $73 billion spent on coal extraction, and $48 to $96 billion spent on oil and natural gas extraction. Electricity will cost between $98 and $151 billion for generation and supply, with an additional $41 to $81 billion spent on new capacity; for totals of $222 to $401 billion[19].



As large as the projected expenses become in 2000 and 2015, they still represent similar fractions of the anticipated GDP. Expenses for extraction, electricity generation and newly installed electrical generation capacity will increase from the 1995 value of 5.6%, to between 6.1% and 6.9% of a $1.1 trillion GDP in 2000, and between 6.4% and 11% of the anticipated $3.47 trillion GDP in 2015. Since the Chinese have been willing and able to devote similar fractions of their GDP to exactly this type of investment in the past, it is reasonable to assume that they will continue to do so in the future.

Since it is unlikely that the Chinese will spend 11% of their GDP in this fashion, this data indicates that the "Standard" scenario with a 6.4% GDP fraction in the year 2015 is much more likely to represent actual energy resource development in China than the "Maximum" scenario.

[19] Figures do not include associated costs such as resource transport, nor do they include the costs of associated infrastructure such as rail lines, new highways, power transmission lines or the like.